Deep Learning and Applications towards Smart City

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Abstract

Smart Cities produce large amount of data due to the implementation of Internet of Things. Machine Learning, especially Deep Learning, will play an important role for knowledge extraction from Big Data in Smart City. Deep Learning has been extremely successful in many fields such as image processing and natural language processing. This paper gives brief reviews about Deep Learning and applications towards Smart City.

Keywords: Smart City, Internet of Things, Big Data, Machine Learning, Deep Learning.

1. Introduction

In the last two decades, there are many modern cities around the world developing to be a Smart City. Cities are judged to be smart based on vision, leadership, budget, financial, support programs, environment policy, innovation ecosystem, people-centricity, talent readiness, and the government's track record [1]. The Internet of Things (IoT) and Big Data are two of the important keys for smart cities implementation. Big data has consequences for smart city to get valuable insights as the expansion of large amount of data retrieving the IoT sensors. Based on a large amount of data collected through various sources, big data can be used to create decision models in various areas for a future impact on the lives of citizens in many aspects. In addition, machine learning plays an important role in analyzing and learning information from big data. Deep learning is one of many methods of machine learning that has been applied for many application domains include health care, machine translation, automatic text generation, image recognition, captions creation, auto driving, advertising, Earthquake prediction, finance, and forecasting [2], [3], [4]. This paper will focus on the reviews of deep learning and applications towards smart city aspects.

2. Related Literature

2.1 Smart City

The aim of smart cities is to provide a better life for the citizens as well as more connected life with sustainability and efficiency. Smart cities are expected to improve citizen lives to be better for having less pollution, garbage, parking problems, crimes, and having more energy savings [1].

Smart city ecosystems [5] should have the following characteristics. Humans need to interact with the systems to provide their feedback. Many sensors and devices generate data at a high rate. The system should learn and improve itself from previous experiences. A general, dynamic, and continuous learning mechanism must evolve over the time. Moreover, the data generated are uncertainty and noisy.

Based on [6] there are many services provided by smart cities including governance, health, education, transportation, sport, safety, finance, economy, energy, environment, climate change, housing, population, social conditions, recreation, culture, telecommunication, urban/local agriculture, food security, urban planning, solid waste, wastewater, and water management. In smart cities, services are connected to each other as well as to the citizens through the Internet of Things.

2.2 Internet of Things

The Internet of things (IoT), sometimes called Internet of Everything (IoE) or Internet of Anything (IoA), is the network of computers, smartphones, machines, vehicles, home appliances, tools, devices, sensors, gadgets, and other electronics equipment with connectivity lets everything to connect, interact, and exchange data. With IoTs, systems can integrate things across smart cities including vehicles, traffic lights, surveillance cameras, manufacturing machinery, finance industries, healthcare devices, airplanes, and more.

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IoT allows environment to be sensed and machines to be controlled remotely across the Internet infrastructure [7], [8]. A large number of IoT devices and machines integrated to the system produce a large volume of data with variety data collecting devices leading to Big Data [9].

2.3 Big Data

Data become big when many sources are connected. The various data sources can be from software systems, IoT hardware devices, and human users generated. Big data have the characteristics of large-volume, heterogeneous, distributed and decentralized sources. Big data seek to explore complex and evolving relationships among data [10]. Big data are defined to have 3V that are Volume, Velocity, and Variety [11]. In addition, nowadays big data also defined to 5V with 2 more characteristics on Veracity and Value [12]. Volume refers to the quantities of data. Velocity refers to the speed of data being generated, collected, and analyzed. Variety refers to the different types of data. Veracity refers to the quality or trustworthiness of the data. Value refers to the worth of the data being extracted and turned into. Big data analytic framework in smart city is mandatory. In addition, it is very important that data must turn into meaningful patterns, decision models, or knowledge for further smart city service applications. Machine learning especially deep learning is one of the challenge solutions for smart cities.

2.4 Deep Learning

Deep learning is one of hot research topics in machine learning applications. Deep learning approaches are usually have more parameters to adapt during learning than the traditional machine learning techniques. Like traditional methods, deep learning can be supervised, semi-supervised, unsupervised, and reinforcement learning. Deep learning networks compose of many types such as deep multilayer perceptron neural networks, deep belief networks, convolutional neural network, and recurrent neural networks. Deep learning methods have been applied to many fields. Convolutional neural network (CNN) [13] works very well with image processing and computer vision. Recurrent neural network (RNN) such as long short-term memory (LSTM) [14] and gated recurrent unit (GRU) [15] networks have been applied successfully with to time series data prediction, audio and speech recognition, natural language processing, and machine translation.

3. Deep Learning Applications in Smart City

In the smart cities, there are many smart applications have been proposed to serve the citizens in the cities. To mention some there are Smart Healthcare, Transportation, Autonomous Vehicles, Smart Parking, E-commerce, and Education.

3.1 Smart Healthcare

Healthcare is inspiring for smart cities in which machine learning especially deep learning methods are applied for healthcare applications. Gao et al. [16] proposed a deep learning network called recurrent 3D convolutional neural network (R3D) to extract spatial-temporal features that are fed into a long short-term memory (LSTM) recurrent neural network. The 3D convolutional network receives video streaming inputs and captures short-term spatial-temporal features that are being fed into the LSTM. The LSTM output feature captures long-term spatial and temporal data, which represent a high level of human action that can be used as a remote medical observation.

In addition, Muhammed et al. proposed UbeHealth [17] that applies edge computing, deep learning, big data, high-performance computing (HPC), and the Internet of Things (IoT) to healthcare framework. Deep learning, big data, and HPC are used to predict network traffic, which in turn are used by the Cloudlet and network layers to optimize data rates, data caching, and routing decisions. Moreover, Said et al. [18] also proposed a deep learning approach for vital signs compression and energy efficient delivery in mHealth Systems. The system proposed to handle an increasing number of chronic disease patients, continuous health monitoring are mandatory for health-care providers. These works are good frameworks for Healthcare for smart cities.

3.2 Transportation

There are a number of deep learning projects working towards transportation applications for smart cities. For example, Jung and Sohn [19] proposed a deep learning architecture to predict where bus passengers would go to using data entry only from smart-card data. The proposed model architecture is based on multilayer perceptron consisted of four layers: an input layer, two hidden layers, and an output layer.

Moreover, Wang et al. [20] proposed surveillance-based vehicle type recognition system implemented using only labels from Web data. This overcomes the manual task labeling data from surveillance images for training. Transfer learning is used to the objective function of the traditional convolutional neural network. The results demonstrate that the proposed recognition method outperforms existing deep learning methods when the training and test data are taken from different imaging systems.

In addition, Li et al. [21] introduced an intelligent transportation System in Macao based on deep self-coding learning. The researchers also combine the deep belief network model and support vector regression classifier as their prediction model, and use the deep belief network model to learn traffic flow characteristics.

3.3 Autonomous Vehicles

Many researchers and scholars contribute their work for autonomous vehicles in smart cities. Zhang et al. [22] proposed deep reinforcement learning techniques for enabling model-free unmanned vehicles control. This work uses convolutional neural network for feature extraction of the necessary information, then makes decisions under the guidance of the deep Q network. Vehicles can cruise in the city without control and collect most required data in the sensing region. Moreover, NVIDIA has created a deep learning neural-network-based system called PilotNet. It outputs steering angles given images of the road. Road images paired with the steering angles generated by a human driving a data-collection car were used to train PilotNet. PilotNet can successfully perform lane keeping in many driving conditions. Deep learning neural networks show to have the capability of learning features [23].

3.4 Smart Parking

In big cities, there ae many cars on the streets and usually there are many problems with parking lots. Finding parking space is possible in the smart cities. For smart parking solutions, the cities need to install IoT sensors or cameras at the parking space, so that the sensors can send out data to central systems. Users then can receive information via smart phone and know where to go for parking spots.

Recently a smart parking sensing and information system that disseminates the parking availability information for public users in a cost-effective and efficient manner has been proposed by Chen et al. [24]. In this work, the hardware is built on advanced wireless sensor networks and cloud service through the Internet. The parking information provided to the users is set in the form of occupancy rates and expected cruising time. The analytical algorithm in this work processing both historical and real-time data.

Additionally, Bura et al. [25] proposed a smart parking by deploying cameras with zoom-lens and motorized head to capture license plate numbers by tracking the vehicles entering or leaving the parking lot. Deep learning neural network is equipped with wide-angle fish-eye lens cameras used to monitor the large parking lot. This work is designed to be more adaptable and affordable smart parking system via distributed cameras, edge computing, data analytics, and advanced deep learning algorithms.

3.5 E-commerce

Deep learning can be applied for e-commerce applications in smart cities in many aspects. Wu et al. [26] proposed an end-to-end neural matching framework for e-commerce sponsored search based on recurrent neural network (RNN) to encode user behavior sequence. In the framework, there are two tasks: vector-based ad retrieval and neural networks based ad pre-ranking. The vector-based ad retrieval applies user recent behavior sequence to retrieve relevant ad candidates

without the constraint of keyword bidding. The deep neural network model is employed to perform the global pre-ranking of ad candidates from multiple retrieval paths.

Besides, a deep learning based smart system for selection of optimal product images in e-commerce is proposed in [27]. The smart image selection system creates an image set that provides relevant information in an orderly manner for every product in the catalog. The system performs aggregation, quality and compliance assessment, classification, de-duplication, and image re-ordering. The selected images are reordered to reveal the product important information details to the customer.

In addition, Shankar et al. [28] proposed a unified end-to-end approach to build a large scale visual search and recommendation system for e-commerce. Deep learning based on convolutional neural network architecture was used to capture the notion of visual similarity, across several semantic granularities.

3.6 Education

In digital era, there are many e-learning systems provide electronics courses. E-learning become new business in industrial 4.0 period. Digital and lifelong learning has been continuously increasing. New demand on digital transformation from normal classroom to distance e-learning paradigm.

Many researchers have come up with new proposal for smart education. Mehmood et al. [29] proposes a personalized ubiquitous e-teaching and e-learning called UTiLearn framework that influences by the Internet of Things, big data, supercomputing, and deep learning. The system provides enhanced development, management, and delivery of teaching and learning in smart cities. In addition, Pacheco et al. [30] proposed smart classrooms aided by deep neural networks inference on mobile devices. A smart classroom prototype was implemented on-device equipped with deep learning inference to assist the activation of classroom devices such as lights, door lock and multimedia projector, via smartphones. It provides a simple user interface to remote control while optimizing energy consumption.

Additionally, Kim et al. [31] proposed an intelligent system that can provide real-time guidance to class presenters to improve the quality and memorable of their presentations by letting the presenter to adjust the hand gestures, facial expressions and body language in real time. The proposed system includes multi-sensing, emotional recognition, deep learning, high-performance GPU computers and feedback systems.

4. Summary

Deep learning applications are challenged task for smart cities since in the smart cities have a large number IoT devices, big data are generated and then can be fed to deep learning models to extract meaningful patterns for further decision making for smart cities services. Deep learning shows large impact to the machine learning community in many applications related to image processing, signal processing, natural language processing, and time series analysis. From state-of-art literature reviews, there many deep learning applications proposed for services in smart cities. Large majority of deep learning techniques are based on convolutional neural network (CNN), long short-term memory (LSTM), gated recurrent unit (GRU), and Deep Multilayer Perceptron neural network (DNN). The application domains includes Healthcare, Transportation, Autonomous Vehicles, Parking, E-commerce, Education, and many more.

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